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BALTIMORE, MARYLAND

WELDING SPECIFICATIONS FOR
ANPP CORROSION PROGRAM
TEST HEAT EXCHANGERS
(INCONEL, MONEL AND NICKEL)

MND-E-2499

March 8, 1961

61-2-34

XEROX

J. F. O'Brien
PROJECT ENGINEER



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FOREWORD

This report is submitted by the Nuclear Division of The Martin Company to the Nuclear Power Field Office, Engineer Research and Development Laboratories, U.S. Army Corps of Engineers, in compliance with Contract DA-44-009-ENG-3581. The report describes the effort involved in the generation of welding specifications for test heat exchangers where Inconel, Monel and nickel are used in the fabrication.

MNI-E-2484

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SUMMARY

Developmental welding was performed in conjunction with fabrication of heat exchangers for the ANPP Corrosion Test Program. Satisfactory processes were developed for: (1) overlaying carbon steel tube sheet material with Inconel, Monel and nickel; (2) seal welding Inconel, Monel and nickel heat exchanger tubes to their respective tube sheets; and (3) seal welding clad tube sheets to the primary shell. Specifications for these welds were prepared and are included in this report.

I. INTRODUCTION

The primary purpose of the ANPP Corrosion Test Program is to test the corrosion characteristics of various materials for use in heat exchangers. As it is desirable to determine the corrosion characteristics in a dynamic system, heat exchangers are fabricated from the desired materials, installed in a heat exchanger test loop and tested under conditions of controlled heat flux and primary and secondary water compositions. For a more detailed discussion of the test program, as well as vessel fabrication techniques, see MND-E-2415, Martin-ANPP Corrosion Testing Program--Methods and Procedures.

Among the materials to be tested were Inconel, Monel and nickel. In order to approximate actual heat exchanger fabrication practice, the tube sheets of the vessels were of carbon steel and were overlaid with the above materials. The tubes were wrought material of the desired test compositions. The primary shell of the heat exchanger was Type 304 stainless steel and the secondary shell was carbon steel.

This set of conditions raised several problems. The procedure for overlaying stainless steel on carbon steel is fairly well known, but the application of Inconel, Monel and nickel was not. Also, for nuclear use, it is common practice to both roll and weld the heat exchanger tubes to the tube sheet. This procedure required qualification. In addition, the particular heat exchanger design used required a seal weld at the junction of the primary shell and the tube sheet to prevent exposure of the carbon steel base of the tube sheet to the primary water. Figure 1 shows a typical heat exchanger design; the three welds under discussion are indicated.

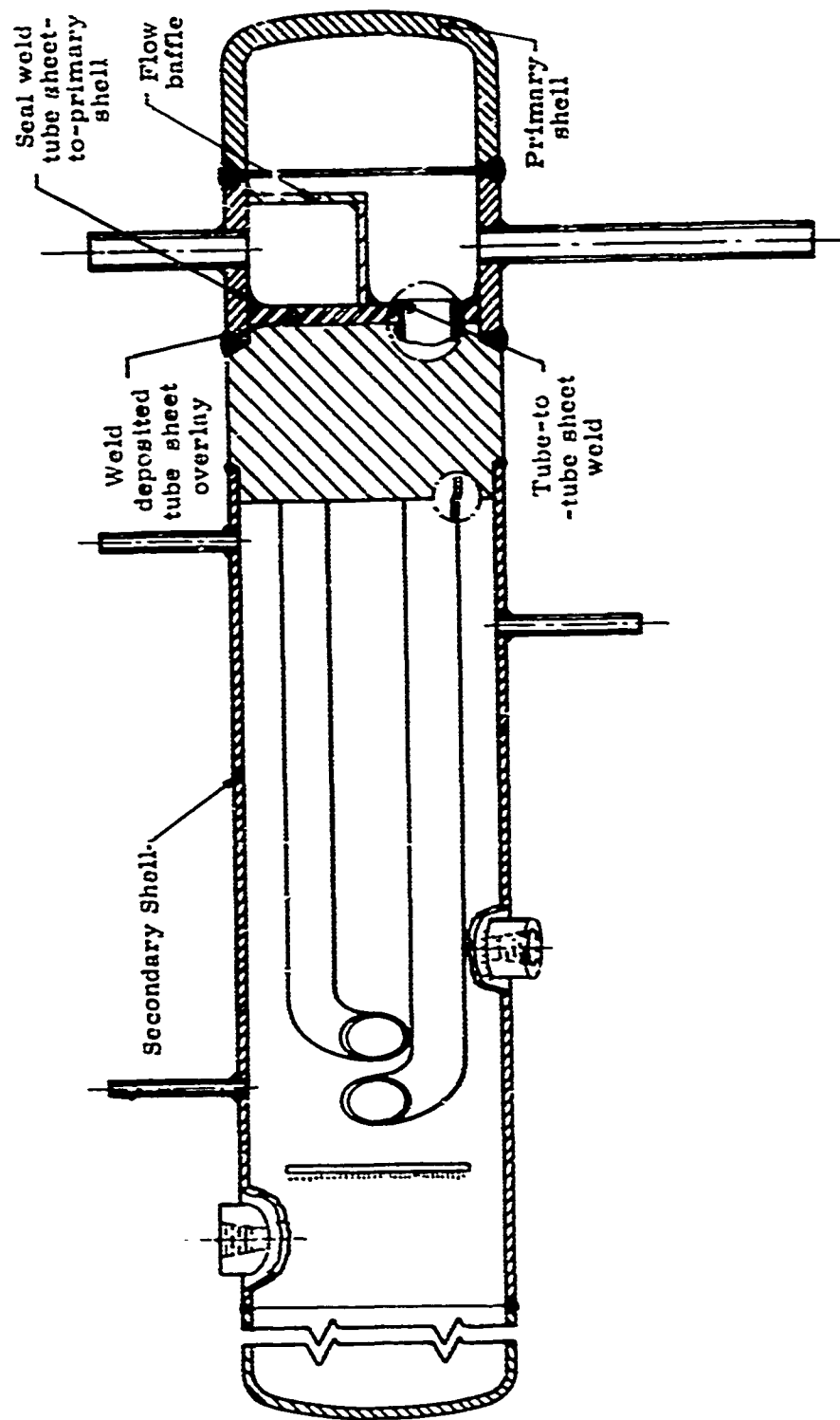
Based on the requirement to fabricate heat exchangers in the configuration described above, welding specifications were generated. They covered:

- (1) Overlaying of carbon steel with Inconel, Monel and nickel.
- (2) Seal welding the Inconel, Monel and nickel tubes to their respective clads.
- (3) Seal welding the primary shell to the tube sheet clad.

These specifications are found in the appendixes to this report.

It should be pointed out that, in each case, the objective was to determine a set of conditions which would result in an acceptable weld. No attempt was made to establish an optimum set of conditions nor to determine an allowable range of deviation on any param-

eters. Hence, it is merely stated that adherence to the specifications will result in a weld which is reliable and satisfactory for this application.



MND-E-2489

Fig. 1. Typical Float Exchanger Design Showing Three Types of Welds Which Were Investigated

II. OVERLAYING CARBON STEEL WITH INCONEL, MONEL AND NICKEL

The requirements for the cladding on the tube sheet were:

- (1) 1/4-inch minimum thickness after machining.
- (2) Nominal composition of Inconel, Monel and nickel.
- (3) Sufficient ductility to pass the standard guided bend test in the transverse side bend position.
- (4) No surface pits or cracks.

Representatives of the International Nickel Company were consulted concerning the various methods of weld clad application. Considering the sizes and quantity of parts to be clad and the many variables introduced by the different methods, a decision was made to use the metal arc welding method employing flux-coated electrodes.

In this study, two compositions of base metal were used. Type 1030 was overlaid with Inconel only and SA 105-II steel was overlaid with Monel or nickel. The allowable composition ranges of the base metals are given in Table 1.

The electrodes chosen for use were Type 140 Monel, 141 nickel and BP-85 Inconel, all supplied by the International Nickel Company. The procurement of these electrodes is covered by Specification MIL-E-17496-D and the electrodes are designated 4N10 (Monel), 4N11 (nickel) and 4N85 (Inconel). Table 2 lists the specified compositions of these electrodes.

Test blocks 6 inches long, 4 inches wide and 2 inches thick were overlaid with each material. The procedures established with the test blocks were used to overlay tube sheets for use in the test heat exchangers.

TABLE 1
Composition Limits of Tube Sheet Base Material (%)

	<u>C</u>	<u>Mn</u>	<u>P</u> (maximum)	<u>S</u> (maximum)	<u>Si</u>
1030	0.28 to 0.34	0.60 to 0.90	0.040	0.050	-
SA 105-II	0.35 maximum	0.90 maximum	0.050	0.050	0.35 maximum

TABLE 2
Chemical Composition of Deposited Weld Metal (%)

	<u>Ni</u>	<u>Cu</u>	<u>Mn</u>	<u>Fe</u>	<u>Si</u>	<u>C</u>	<u>S</u>	<u>Ti</u>	<u>Al</u>	<u>Other</u>
4N11 92 min	0.25	0.75	0.75	0.75	1.25	0.10	0.02	1.04 to 4.0	1.0	0.50
4N10 62.0 to 70.0	rem.	2.5	2.5	2.5	1.25	0.15	0.025	1.5	0.75	0.50

4N85 A modification of 4N12--exact allowable composition unknown but described in MIL-E-174980

The procedures used for the various materials were essentially the same. The base metal surface was prepared by machining to remove all scale and irregularities. The surface was cleaned with acetone to remove all oil after the machining operation. The block was then heated to 300° F with an acetylene-oxygen torch to provide the weld preheat. The temperature was measured with a surface pyrometer. The block was positioned and welding was performed in the downhand (flat) position.

During the welding of the initial weld layer, the arc was manipulated in such a manner that it always played on a pool of molten metal. Forward speed for a given value of current is somewhat self-regulating in that the arc is moved only as fast as the metal flows. By not arcing directly on the steel base metal, iron dilution of the overlay is minimized and the chance of cracking is decreased.

In this study, after several preliminary test runs were made to establish the welding conditions, a forward speed of approximately 6 inches per minute was maintained for all three materials, with a welding current of 120 amperes DCRP for Inconel and Monel and 130 amperes DCRP for nickel. Average electrode consumption was 10 inches per minute.

Each bead was chipped and brushed to remove flux between passes and ensure against subsequent entrapment of impurities. An interbead temperature of 300 to 400° F was taken as an accepted standard and was maintained while welding was performed. The resultant bead contour is shown in Fig. 2. The bead sequence used is shown in Fig. 3. Four layers of weld metal were necessary to obtain a 3/8-inch minimum clad thickness.

The sample blocks were machined to a clean surface and samples were cut for guided bend tests. The remainder of the block was used for checking tube-to-tube sheet welding procedures.

The specimens for guided bend tests were transverse side bend samples 1-1/2 inches wide, 3/8 inch thick and 6 inches long. They were subjected to 2 T radius bend tests as accepted by the ASME Boiler Code. Examination of the surfaces showed no evidence of cold shuts, porosity or other defects in all of the specimens. The bend specimens used are shown in Fig. 4. Dye penetrant checks of all the overlay surfaces showed no evidence of surface defects in any of

the sample blocks. As a further check, the samples were sectioned and hardness traverses made of the overlay and base. The results are shown in Figs. 5, 6 and 7. No objectionable hardening occurred, as evidenced by the small hardness change in the area of the clad interface.

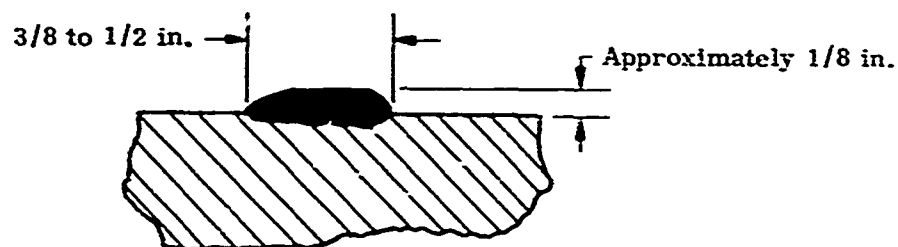


Fig. 2. Typical Cross Section of Bead as Properly Applied
(Note Steep Sides and Minimum Penetration)

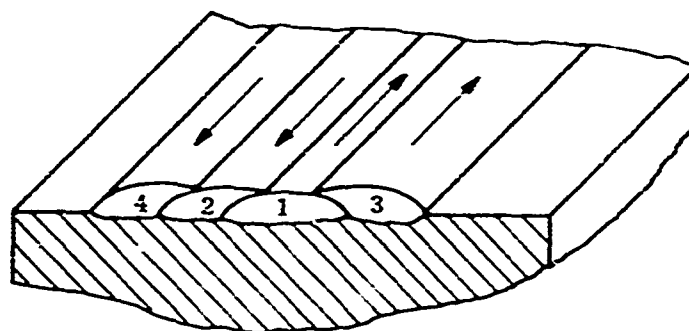


Fig. 3. Proper Bead Sequence and Direction of Travel

After machining the clad surfaces to the finish thickness, samples were taken for chemical analysis by machining the top 1/16 inch. Iron contents were 9.76%, 7.70% and 3.46% for nickel, Inconel and Monel respectively.

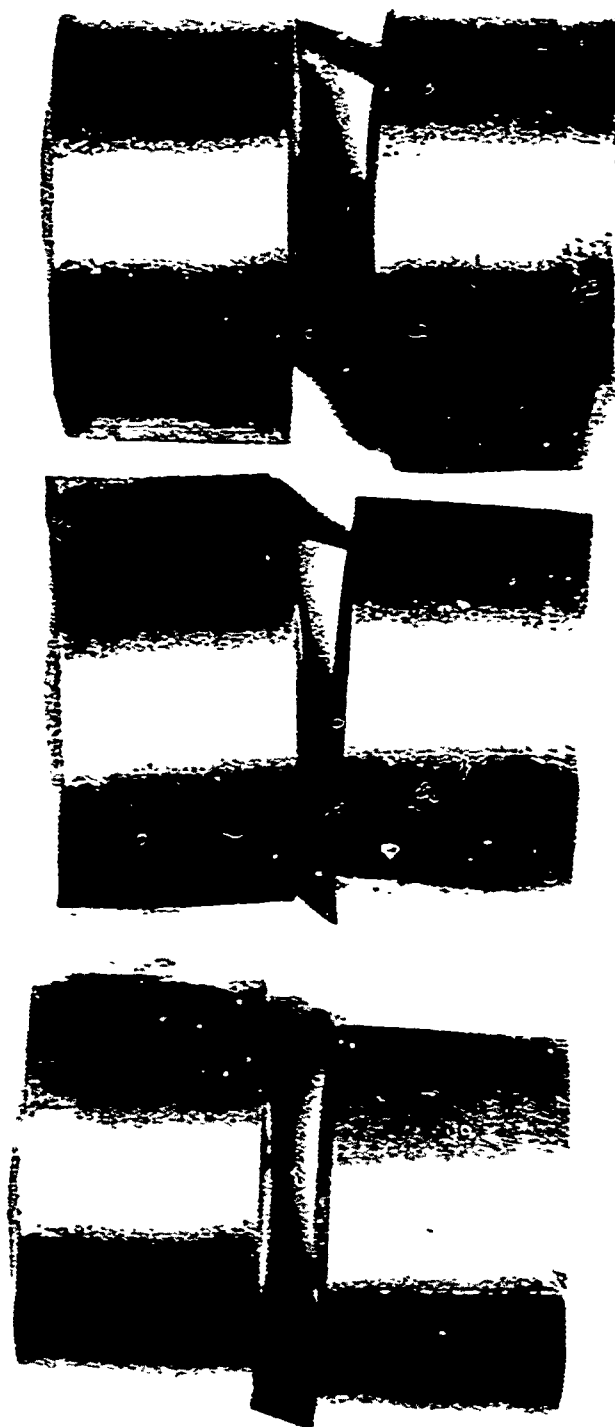


Fig. 4. Transverse Side Bend Specimens

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It may be concluded that high quality overlays of Inconel, Monel and nickel can be applied to carbon steel tube sheet material by the metallic arc welding technique. Welding specifications are given in Appendix A.

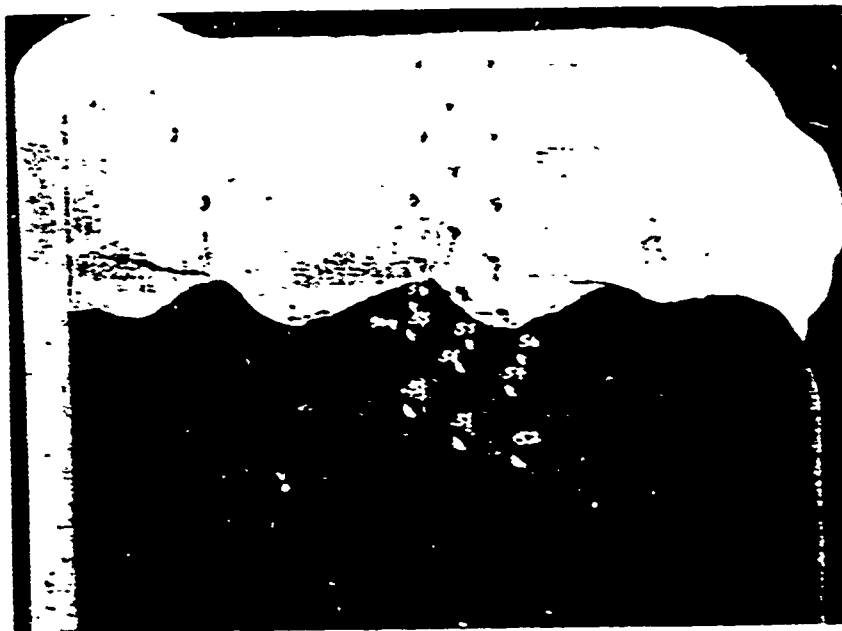


Fig. 5. Inconel Overlay on Carbon Steel Test Block, Showing Rockwell Hardness Traverses (A Scale)

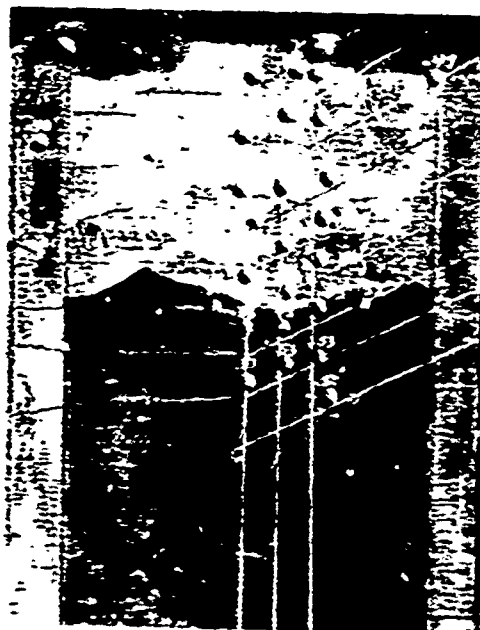


Fig. 6. Monel Overlay on Carbon Steel Test Block, Showing Rockwell Hardness Traverses (A Scale)



Fig. 7. Nickel Overlay on Carbon Steel Test Block, Showing Rockwell Hardness Traverses (A Scale)

III. TUBE-TO-TUBE SHEET WELDS

The following two parameters determined the design of the tube-to-tube sheet joint.

- (1) The weld would not be required to provide mechanical strength to the joint. This would be provided by the mechanical bond through the tube expansion operation.
- (2) The weld was to provide a secondary barrier against leakage. This would require only a discontinuity of the interface between the tube and tube sheet.

To fulfill these requirements, two types of weld were tried. The first type of weld was performed manually. Preparation was simple in that the only requirement was that the tube be positioned to extend beyond the tube sheet a distance equal to its wall thickness, as shown in Fig. 8.

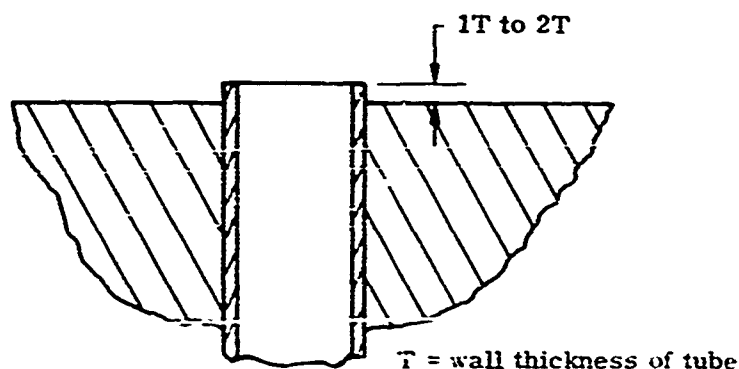


Fig. 8. Tube Position in Tube Sheet Before Welding

The arc was manipulated so that the projection was entirely melted and none of the metal flowed into the tube entrance. Figures 9, 10 and 11 are photomicrographs of typical welds produced by this process.

Figures 12, 13 and 14 show the macro appearance of the tube-to-clad weld joints.



Fig. 9. 1030 Steel Overlaid with Nickel, with Tube Insert
(Magnified 75X)

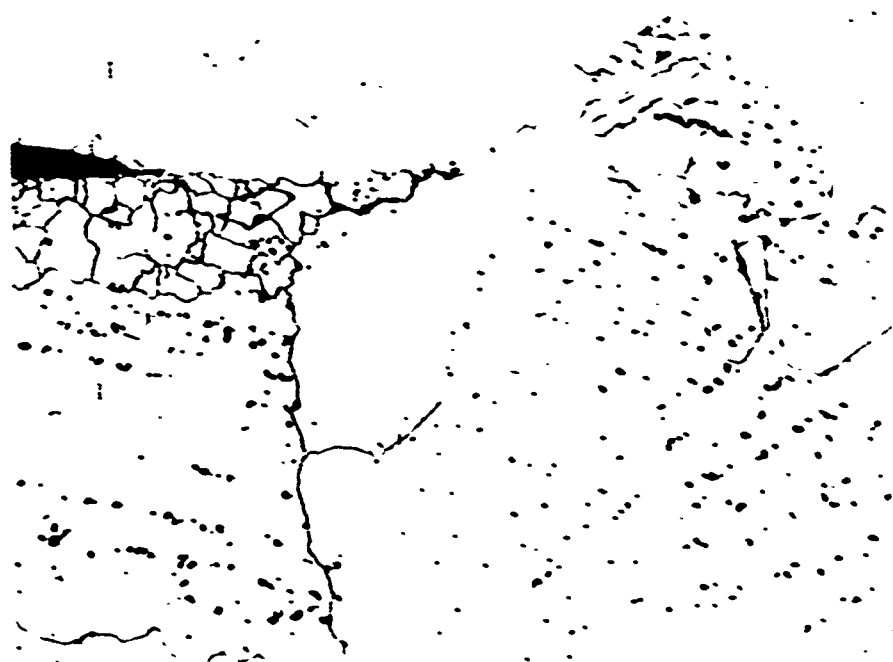


Fig. 10. 1030 Steel Overlaid with Monel, with Tube Insert
(Magnified 250X)

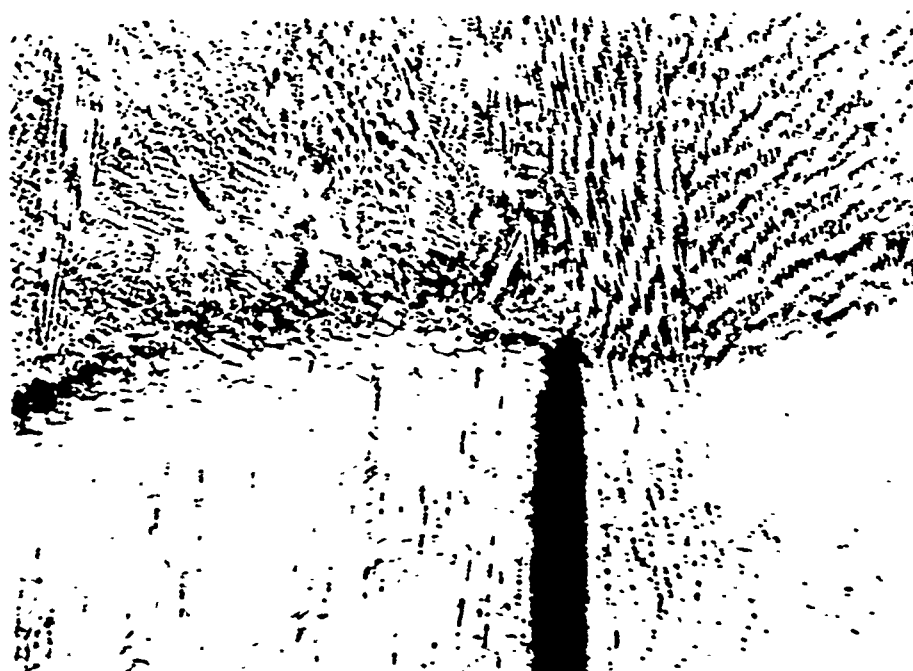


Fig. 11. 1030 Steel Overlaid with Inconel, with Tube Insert (Magnified 75X)



Fig. 12. 1030 Steel Overlaid with Nickel, with Tube Insert (Macrographed 20X)

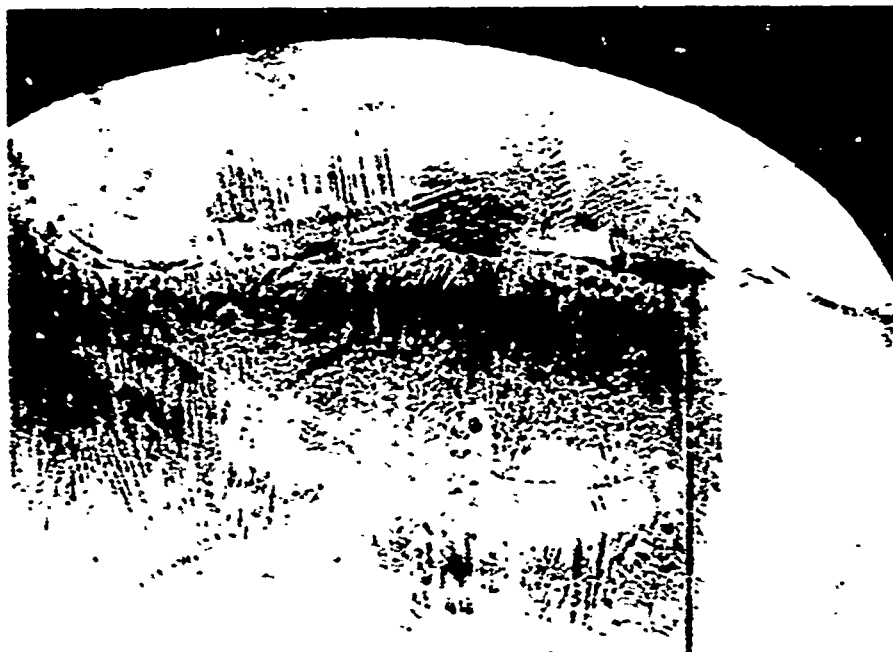


Fig. 13. 1030 Steel Overlaid with Monel, with Tube Insert
(Macro photographed 18X)



Fig. 14. 1030 Steel Overlaid with Inconel, with Tube Insert
(Macro photographed 18X)

The second method was automatic welding. Preparation was more complex, requiring that a trepan groove be cut into the tube sheet around each tube. Figure 15 shows the dimensions of the trepan used.

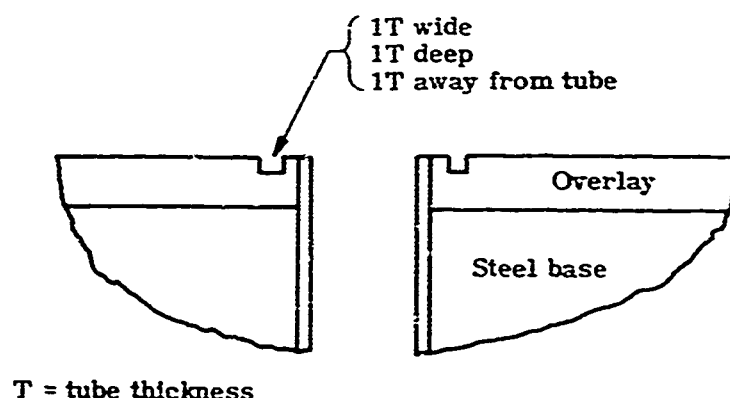


Fig. 15. Tube-to-Tube Sheet Joint--Automatic Weld

The tube sheet was rotated with the center of the hole as the center of rotation. Identical results could be achieved by having the torch rotate. The welding of each joint was completed in 1-1/2 turns of the tube sheet. The welding current was tapered over the last 1/4 revolution to eliminate cratering when breaking the arc.

For the number of pieces to be welded, the manual technique was preferable, provided weld quality was good. As a final check, several tubes of each type were welded in place. Twenty metallographic specimens of each type material were examined, and these contained no visible cracks or porosity. Therefore, the weld procedure was considered satisfactory. The weld conditions were 120 amperes DCSP for Monel and Inconel and 140 amperes DCSP for nickel, with a travel speed of approximately 3 inches per minute. No filler was added. Specifications for the weld are given in Appendix B.

IV. PRIMARY SHELL-TO-TUBE SHEET WELDS

The configuration of the primary shell-to-tube sheet joint is shown in Fig. 16. The load-bearing weld was made according to existing specifications and, therefore, is not treated here. The internal seal weld was of interest, for with a failure here, the carbon steel underlayer of the tube sheet would be exposed to the primary water. As this is a weld between stainless steel and a nickel alloy, "Inco-Weld A" filler metal was used with each type of clad. To check weld quality, 1/4-inch stainless plate was fillet-welded to the edge of the sample blocks. The weld was completed in one pass, adding enough weld metal to obtain the required 1/4-inch fillet. The completed weld was dye-checked and subjected to a bend test used in qualifying fillet welds and found satisfactory on both counts. Final weld conditions were 125 amperes DCSP, 4 inches per minute travel and 1/16-inch RN6A rod added at a rate of 16 inches per minute. Specifications for the weld are given in Appendix C.

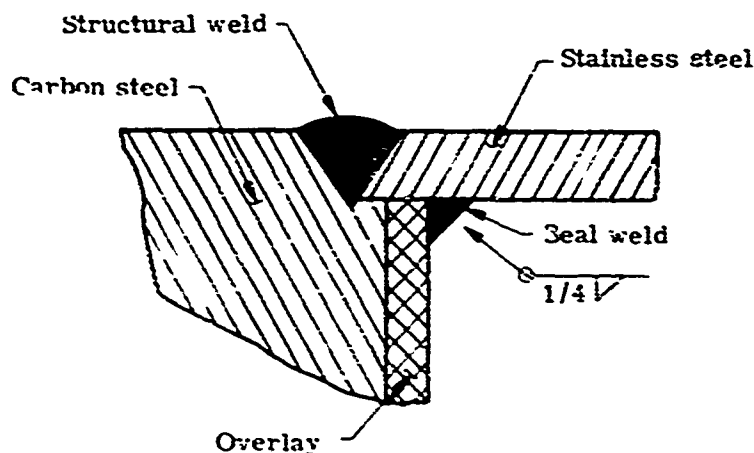


Fig. 16. Typical Tube Sheet-to-Primary Shell Joint Configuration

APPENDIX A

APPLICATION OF NICKEL-BASE ALLOY OVERLAYS ON CARBON
STEEL BY THE METALLIC ARC WELDING PROCESS

APPLICATION OF NICKEL-BASE ALLOY OVERLAYS ON CARBON STEEL BY THE METALLIC ARC WELDING PROCESS

1. SCOPE

1.1 This process establishes the engineering requirements for the application of nickel-base alloy overlays on carbon steel plates to be used as heat exchanger tube sheets intended for service at temperatures up to 700°F and pressures up to 2500 psig. The use of base metals or electrodes not covered by this specification shall be approved by the materials engineer associated with the project.

1.2 Overlays greater than 0.250 inch thick may be applied to base metals 2 inches or more in thickness by this process.

2. REFERENCES

2.1 American Society for Testing Materials Standards -

2.1.1 A-105-59T; Forged and Rolled Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service

2.1.2 A-350-57T; Forged and Rolled Carbon and Alloy Steel Flanges, Forged Fittings, and Valves and Parts for Low-Temperature Service.

2.1.3 B-295-54T; Nickel and Nickel-Base Alloy Covered Welding Electrodes.

2.2 Military Specifications -

2.2.1 MIL-E-17496D; Electrodes, Welding, Covered: Nickel Base Alloy, and Cobalt Base Alloy;

2.3 Martin Nuclear Process Specifications -

2.3.1 NPS 04-001; Metallic Arc Welding of Chromium-Nickel Austenitic Stainless Steel Pipe

Prepared by <i>F. J. Gillen</i>	Checked by <i>W. B. King Jr.</i>	NUCLEAR PROCESS SPECIFICATION Application of Nickel-Base Alloy Overlays on Carbon Steel by the Metallic ARC Welding Process	
Materials <i>J. Mueller</i>	Manufacture <i>[Signature]</i>		
Project <i>C. Eckelburger</i>	Quality Control	MARTIN NUCLEAR	01-007T
	Customer		
		BA111MORE, MD	Date November 1, 1960

2. REFERENCES (Continued)

2.4 Others -

- 2.4.1 Bulletin T-2; Fusion Welding of Nickel & High Nickel Alloys; International Nickel Co., New York

3. REQUIREMENTS

- 3.1 Welder Qualification - Welders shall be qualified in accordance with Section II of NPS 01-004 or by an equivalent procedure, as approved by the materials engineer associated with the project.

3.2 Materials -

- 3.2.1 Base Metal - The base metal shall conform to ASTM specifications A 105-59T or A 350-57T.

- 3.2.2 Filler Metal - Electrodes shall be selected in accordance with Table I, Fresh packages shall be used whenever possible; electrodes that have been exposed to the air for more than two days shall be baked in accordance with the manufacturer's recommendations.

3.3 General Requirements -

- 3.3.1 Positions - Overlays made in conformance with this specification shall be welded in the flat position.

- 3.3.2 Surface Preparation - The surface to the overlaid shall be free of scale, grease, oil, paint or other foreign matter. This may be accomplished by machining, pickling, torch descaling, or washing with acetone or other approved solvents as required.

- 3.3.3 Repair Approval - All repairs must be approved by the materials engineer and stress engineer associated with the project and by the inspector.

- 3.4 Safety Precautions - Suitable protective clothing and face shields shall be worn by welders as required for personal safety. Adequate ventilation shall be provided to assure removal of fumes.

3.5 Procedure -

- 3.5.1 Welding Current - The welding shall be accomplished with direct current connected with reverse polarity, i.e., the base metal shall be the negative pole of the welding arc. Welding currents shall be in accordance with recommendations of the electrode manufacturers or as specified by Engineering.

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NUCLEAR PROCESS SPECIFICATION

A-5

3. REQUIREMENTS (Continued)

3.5.2 Electrodes - Electrodes of 5/32 inch diameter shall be used.

3.5.3 Preheat - The base metal shall be heated to a temperature between 300 and 400°F before welding. Temperature may be measured with a "Tempil-Stik" or by other suitable means adjacent to but not on the surface to be overlayed. Under no circumstance shall "Tempil-Stik" marks be made on the surface to be overlayed.

3.5.4 Welding Technique - The proper bead contour is thick and wide without feather edges (see Figure 1). This can be achieved by using a slow forward speed of approximately 6 inches/minute at a measured current of approximately 125 amps. The arc shall play on a thick pool of molten weld metal. Weave beads shall be avoided. Using the procedure properly, iron dilution of the weld metal is minimized.

3.5.5 Bead Sequence and Overlap - The proper bead sequence is shown in Figure 2. An overlap of 25% will usually suffice to obtain an overlay that will require a minimum amount of machining for clean up.

3.5.6 Inter-Bead Cleaning - All slag, flux, and defects evident from visual inspection shall be removed from each weld bead, and repairs made as necessary, before the next bead is laid. Flux, oxides, etc., shall be removed with a chipping hammer and steel wire brush. Defects shall be removed by grinding with rubber or resin bonded aluminum oxide or silicon carbide wheels.

3.5.7 Inter-Layer Temperature - As a layer is completed, the application of the next layer shall not commence until the temperature of the base material is between 300° and 400°F. The temperature may be measured as described in Section 3.5.3 of this specification.

3.5.8 Post-Heat Treatment - Stress relieving or other heat-treatments shall not be attempted.

4. QUALITY ASSURANCE PROVISIONS

4.1 General - The presence of an inspector shall not relieve the welder of responsibility of insuring that all overlay welds are made to meet the requirements of this specification. The inspector may reject or cause to be repaired or rewelded any overlay which does not meet any part of this specification.

4.2 Pre-Weld Inspection - The inspector shall determine that the base metal, electrodes and surface preparation are in accordance with this specification.

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NUCLEAR PROCESS SPECIFICATION

4. QUALITY ASSURANCE PROVISIONS (Continued)

4.3 During Welding - The inspector shall monitor the welding operations to assure that they are being carried out in compliance with this specification. The inspector shall have defects in individual passes repaired allowing the welder to proceed with the next pass.

4.4 Visual Inspection - The appearance of the completed welds shall indicate that they were made in a workmanlike manner. Flaws such as cracks, obvious porosity, unfilled craters, etc., shall not be evident. The completed weld shall be inspected by the dye penetrant technique after machining.

4.5 Inspection Record - The welding inspector shall record on a suitable form data describing the fabrication of each overlay and the results of the inspection. The information to be recorded shall include, as a minimum, the names of welder and inspector; drawing number and part number; any deviations from this specification or the drawings (with signatures of personnel authorizing each deviation); a listing of necessary repairs (with signatures of personnel authorizing such repair); and the number, title, and issue date of the specification followed. Inspection records shall be filed permanently by Quality.

TABLE I

ELECTRODE REQUIREMENTS FOR OBTAINING DESIRED OVERLAY

Overlay	AWS-ASTM Electrode Classification	International Nickel Co. Designation	Applicable ASTM Specification	Applicable (Military) Specification
Monel	E4N10	"140" Monel	B295-54T	MIL-E-17496D
Nickel	E4N11	"141" Nickel	B295-54T	MIL-E-17496D
Inconel	E4N85 Tentative	"BP85" Inconel	--	MIL-E-17496D

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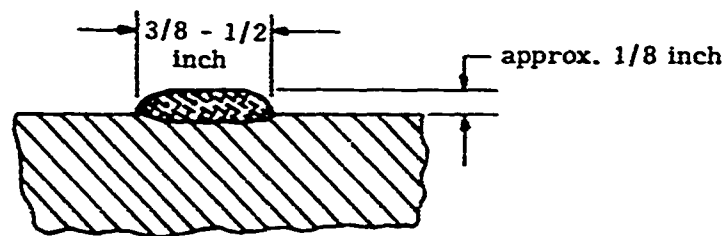


Figure 1
Typical Cross Section of Bead as Properly Applied - Note Steep Sides
and Minimum Penetration

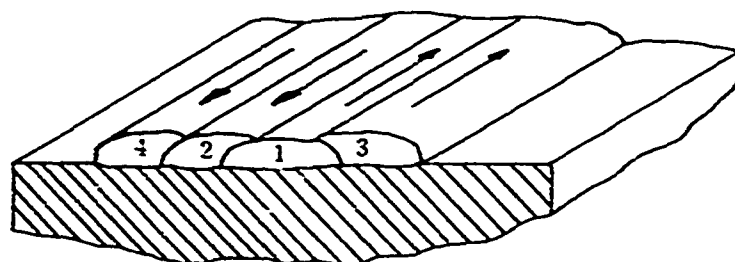


Figure 2
Proper Bead Sequence and Direction of Travel

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APPENDIX B

SEAL WELDING OF NICKEL-BASE ALLOY HEAT EXCHANGER
TUBES TO TUBE SHEET

SEAL WELDING OF NICKEL BASE ALLOY HEAT EXCHANGER TUBES TO TUBE SHEET

1. SCOPE

- 1.1 This specification establishes the requirements for the seal welding of nickel and high nickel alloy heat exchanger tubes to tube sheets of similar composition or with an overlay of similar composition after the tube has been positioned by an expansion roller.
- 1.2 The weld produced by this process is for crevice sealing purposes only and imparts no mechanical strength to the joint.

2. REFERENCES

2.1 Martin Nuclear Process Specification -

- 2.1.1 NPS 01-007 Application of Nickel-Base Alloy Overlays On Carbon Steel By The Metallic Arc Welding Process

2.2 American Society for Testing Materials Standards -

- 2.2.1 ASTM B 160 - 58T Nickel Rod and Bar
- 2.2.2 ASTM B 164 - 58T Nickel-Copper Alloy Rod and Bar
- 2.2.3 ASTM B 166 - 58T Seamless Nickel and High Nickel Alloy Condenser, Evaporator, and Heat-Exchanger Tubes

3. REQUIREMENTS

- 3.1 Welder Qualification - The welder's qualification shall be as approved by the materials engineer associated with the project.

3.2 Materials -

- 3.2.1 Tube Sheet - The composition of the tube sheet material shall conform to or be produced by any one of the following specifications:

ASTM B 160 - 58T

ASTM B 166 - 58 T

ASTM B 164 - 58T

NPS 01-007

Prepared by <i>F. Giller</i>	Checked by <i>H. D. King Jr.</i>	NUCLEAR PROCESS SPECIFICATION Seal Welding of Nickel Base Alloy Heat Exchanger Tubes to Tube Sheet	
Materials <i>J. Mueller</i>	Manufacturing		
Project <i>C. Eicheldinger</i>	Quality Control	MARTIN NUCLEAR BALTIMORE, MD	01-008T
	Customer		Date November 8, 1960

MND-E-2489

3. REQUIREMENTS (Continued)

3.3 General Requirements -

3.3.1 Positions - Welds made in accordance with this specification shall be made in the downhand position.

3.3.2 Joint Preparation - The joint shall be prepared by expanding the tubes, outward against the tube sheet holes such that a sound mechanical joint is achieved which complies with all engineering requirements. The joint configuration shall be in accordance with Figure 1.

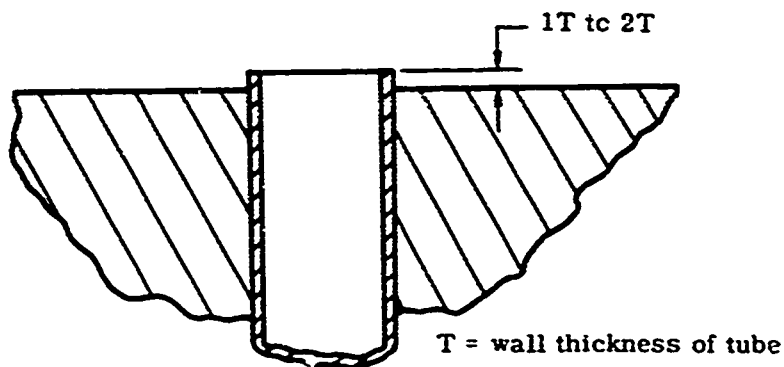


Figure 1

3.3.3 Cleaning - The area to be welded shall be cleaned with acetone or other approved solvent to remove all traces of grease, oil, paint and other foreign matter.

3.4 Safety Precautions - Suitable protective clothing and face shields shall be worn by welders as required for personal safety. Adequate ventilation shall be provided to assure removal of fumes and shielding gas.

3.5 Procedure -

3.5.1 Welding Current - Direct current connected for straight polarity (base metal positive) shall be used.

3.5.2 Technique - The weld shall be completed in a single pass. The electrode shall be positioned such that the arc plays on the tube sheet approximately 1/32 inch from the tube. The proper bead, approximately equal in thickness to the tube wall and 2 to 3 times as wide, is obtained with a current of 120 amps, for Monel and Inconel and 140 amps for nickel with a travel speed of 3 inches per minute.

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NUCLEAR PROCESS SPECIFICATION

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4. QUALITY ASSURANCE PROVISIONS

4.1 General - The presence of an inspector shall not relieve the welder of responsibility for assuring that all welds are made to meet the requirements of this specification. The inspector may reject, and cause to be repaired or rewelded, any joint which does not meet any part of this specification.

4.2 Pre-Weld Inspection - The inspector shall determine that the tube sheet, tubes, shielding gases, and joint preparation are in accordance with this specification.

4.3 Post-Weld Inspection - The appearance of the completed welds shall indicate that they were made in a workmanlike manner. Flaws such as cracks, craters, obvious porosity or unmelted tube projection shall not be evident. The completed weld shall be inspected by the liquid penetrant technique and by pressurizing to 100 psi with air on secondary side with welded joints exposed under water.

4.4 Inspection Record - The welding inspector shall record on a suitable form, data describing the fabrication of each joint and the results of the inspection. The information to be recorded shall include, as a minimum; the names of the welder and inspector; drawing number and part number; any deviations from specification or engineering drawings (with signatures of personnel authorizing such deviation); description of defects and corrective action taken; the number, title and issue date of the specification followed. When a weld is completed to the inspector's satisfaction, he will sign the inspection record to indicate this fact. Inspection records shall be filed permanently by Quality.

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APPENDIX C

SEAL WELDING THE TUBE SHEETS TO PRIMARY SHELL
OF HEAT EXCHANGERS

SEAL WELDING THE TUBE SHEETS TO PRIMARY SHELL OF HEAT EXCHANGERS

1. SCOPE

1.1 This specification establishes the requirements for seal welding heat exchanger tube sheets, made from or clad with nickel and high nickel alloys, to stainless steel primary shells. The heat exchangers are intended for use at temperatures up to 700°F and at pressures up to 2500 psig.

1.2 The weld produced by this process is to prevent crevice corrosion and is not intended to add mechanical strength to the joint.

2. REFERENCES

2.1 Martin Nuclear Process Specifications -

2.1.1 NPS 01-006; Inert-Gas Shielded-Arc Welding of Chromium-Nickel Austenitic Stainless Steel Pipe

2.1.2 NPS 01-007; Application of Nickel-Base Alloy Overlays On Carbon Steel by the Metallic Arc Welding Process

2.2 American Society for Testing Materials Standards -

2.2.1 ASTM A312-59T Seamless and Welded Stainless Steel Pipe

2.3 Military Specifications -

2.3.1 MIL-E-21562 Nickel Alloy Welding Wire

3. REQUIREMENTS

3.1 Welder Qualification - Welders qualified in accordance with NPS 01-006, Section 2, shall be qualified to perform this work.

3.2 Materials -

3.2.1 Tube Sheets - The tube sheet shall have been produced according to specification NPS 01-007 or shall be forgings of Inconel, Monel or Nickel.

Prepared by: <i>F. Geller</i>	Checked by: <i>H.B. King Jr.</i>	NUCLEAR PROCESS SPECIFICATION Seal Welding the Tube Sheets to Primary Shell of Heat Exchangers	
Materials: <i>J. Mueller</i>	Manufacturing: <i>J. Mueller</i>		
Project: <i>C. Escheldinger</i>	Quality Control: <i>C. Escheldinger</i>	MARTIN NUCLEAR BALTIMORE, MD	01-009T
	Customer:		Date: November 16, 1960

3. REQUIREMENTS (Continued)

3.2.2 Primary Shells - The primary shell shall be Type 304 stainless steel pipe as defined by ASTM A 312-59T.

3.2.3 Filler Metals - The filler rod shall be 1/16 inch diameter Type RN6A as defined in MIL-E-21562.

3.2.4 Shielding Gas - Argon of 99.8% minimum purity shall be used.

3.3 General Requirements -

3.3.1 Positions - Welds made in accordance with this specification shall be performed in a downhand position.

3.3.2 Joint Preparation - The joint shall be prepared by machining according to the engineering drawing. The typical configuration is shown in Figure 1.

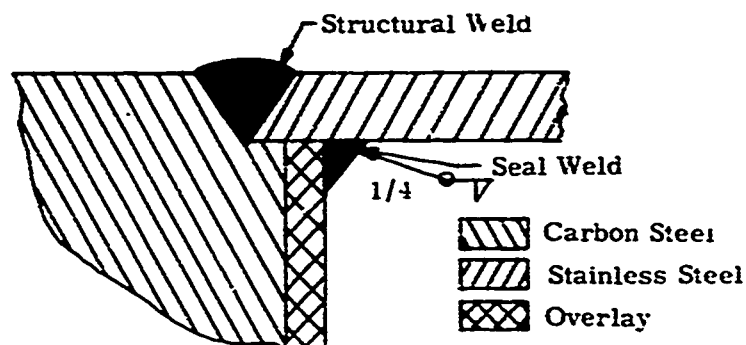


Figure 1

Typical Tube Sheet to Primary Shell Joint Configuration

3.3.3 Cleaning - The area to be welded shall be cleaned with acetone or other approved solvent to remove all traces of grease, oil, paint or other foreign matter. Care must be taken to remove all solvent from the crevice.

3.4 Safety Precautions - Suitable protective clothing and face shields shall be worn by welders as required for personal safety. Adequate ventilation shall be provided to assure removal of fumes and shielding gas.

3.5 Procedure -

3.5.1 Welding Current - Direct current connected for straight polarity (base metal position) shall be used.

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3.5.2 Technique - The weld shall be completed in a single pass. A 1/4 inch fillet is sufficient to effectively seal the crevice. This is obtained with a welding current of 125 amps, 4 inches per minute forward travel speed and adding 1/16 inch rod at a rate of 16 inches per minute.

4. QUALITY ASSURANCE PROVISIONS

4.1 General - The presence of an inspector shall not relieve the welder of responsibility for assuring that all welds are made to meet the requirements of this specification. The inspector may reject, and cause to be repaired or rewelded, any joint which does not meet any part of this specification.

4.2 Pre-Weld Inspection - The inspector shall determine that the tube sheet, primary shell, shielding gases, and joint preparation are in accordance with this specification.

4.3 Past-Weld Inspection - The appearance of the completed welds shall indicate they were made in a workmanlike manner. Flaws such as cracks, unfilled craters, obvious porosity, shall not be evident. The completed weld shall be inspected by the dye penetrant technique.

4.4 Inspection Record - The welding inspector shall record on a suitable form data describing the fabrication of each joint and the results of the inspection. The information to be recorded shall include, as a minimum, the names of the welder and inspector drawing number and part number, any deviations from specification or engineering drawings (with signatures of personnel authorizing such deviation), description of defects and corrective action taken, the number, title and issue date of the specification followed. When a weld is completed to the inspector's satisfaction, he will sign the inspection record to indicate this fact. Inspection records will be filed permanently by Quality.

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